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ABSTRACT

The Collaborative Learning Laboratory (CCL) is a technology-enriched environment for the support of collaborative learning activities. Networking, multimedia, and other computer facilities combine to augment Problem-Based Learning, a collective and student-centered method of instruction that has been used in professional education and is being introduced into secondary education. Problem-Based Learning is described, along with ways in which it can be enhanced through CCL features such as e-talk, the Teaching Case Library, and the Clinical Encounter Simulation Stack. (Contains 12 references.) (Author/BEW)

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The Collaborative Learning Laboratory: A Technology-Enriched Environment to Support Problem-Based Learning

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Abstract

The Collaborative Learning Laboratory (CLL) is a technology-enriched environment to support collaborative learning activities. The laboratory provides a reconfigurable environment of hardware and software including multimedia, networking and other computer-based facilities. In this paper we describe a project to augment Problem-Based Learning (PBL) in the CLL. PBL is a collaborative and student-centered method of instruction that has been used extensively in professional education and is currently being introduced into secondary education. We will describe ways in which PBL, and in particular PBL team meetings, can be enhanced through the affordances of the CLL.

Introduction

Changes in education theory have resulted in various reconfigurations of classrooms. In particular, in the field of medical education a widespread dissatisfaction with the traditional methods of education (Gastel & Rogers, 1989; GPEP, 1984) has led to an alternative approach to teaching—Problem-Based Learning (PBL) (Barrows, 1985; Barrows & Tamblyn, 1980). The PBL approach emphasizes collaborative learning as an alternative to the traditional teacher-centered approach. In traditional classrooms teacher lectures and individual student work form the main learning methods. Essentially the emphasis is on teacher-student interaction as the main ingredient to success. Collaborative learning emphasizes student-student interactions as well as students-expert interactions in the learning/teaching process. The students actively participate in the learning process by attempting to solve a problem or investigate an issue as a group, interacting with each other in their deliberation towards a solution of the problem or understanding of the issue. Examples of collaborative learning include cooperative learning (Slavin et al, 1985), project-based instruction (Blumenfeld et al, 1991), and PBL. Although these methods vary in form, they all have in common an emphasis on participant interaction as the key to their success. Given the success of these methods the next question is how to advance them.

The changes in classroom configurations and educational methods give rise to new needs in the classroom. Current technology often offers means of support to meet these needs and improve the efficacy of these new classrooms through information collection, dissemination, and presentation (Koschmann, Myers, Felovich, & Barrows, in press).

Our paper is concerned with how PBL can be supported and advanced through the use of multimedia and computer technology. Multimedia offers the ability to present information in various and editable formats. Video technology together with computers can present problem data with greater authenticity. Any collaborative environment implies a heavy exchange of information, and success of a collaborative enterprise requires rapid and accurate exchange of this information. Electronic information technology provides various options for rapid collection and distribution of information. Additionally, multimedia technology introduces some new alternatives for information presentation. We intend to show how the already successful PBL method can be supported by multimedia and computer technologies, thereby strengthening and improving its effectiveness.

This paper describes the Collaborative Learning Laboratory (CLL), an experimental platform for the introduction of technology into PBL classrooms. We emphasize that we do not intend to introduce a new way of teaching; instead we plan to support and enhance the already successful PBL classroom.

The paper begins by introducing PBL methods, and describing the traditional practice of PBL. Next the CLL, an experimental platform for technological support for collaborative learning, is presented. The paper then describes how the PBL classroom will work with the technological support afforded by the CLL. Finally, further arguments for technological augmentation of the PBL classroom are presented.

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PBL (Barrows, 1985; Barrows & Tamblyn, 1980) was developed to address various shortcomings in traditional approaches to medical education. The reasons for dissatisfaction with traditional approaches to medical education have been described elsewhere (Gastel & Rogers, 1989; GPEP, 1984). Reforms proposed emphasized the need to engage medical students actively in the learning process (as opposed to being passive recipients of knowledge distributed). Instead of lectures, a more interactive approach of instruction that embedded knowledge acquisition and reasoning development within the context of ultimate use, and encouraged development of self directed learning skills (Collins, Brown, & Newman, 1989; Feltoich, Spiro & Coulson, (1989)) was proposed. PBL uses a collaborative learning methodology to encourage this form of engagement on the part of the students.

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graph LR; A([Problem Formulating]) --> B([Self-Directed Learning]); B --> C([Problem Reexamining]); C --> D([Abstracting]); D --> E([Reflecting]); B --> A; C --> B;
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Figure 1: Stages in the Problem-Based Learning Methodology (from Koschmann, et al, in press).

At the start, the students are presented with a clinical problem. A variety of methods are used to present the clinical case to the students. The preferred method is to have students interview and examine the actual patient (Barrows, 1985). However, due to practical considerations, this practice is generally not feasible and it becomes necessary to simulate this encounter with the patient. Patient encounters can be simulated using "Standardized Patients"—a standardized-patient is someone trained to act as the patient (Barrows, 1987). A second alternative is to use a Problem-Based Learning Module (PBLM) (Distlehorst & Barrows, 1982)—a textual database simulation of the patient encounter (see section below). Whichever method is used, the students are required to go through the steps of interviewing and conducting a physical examination of the patient.

The patient encounter is followed by a phase of self-directed learning. The PBL tutorial group (students and coach) meet to carry on further work on the clinical case. The students, relying on information collected so far and other pertinent prior knowledge, attempt to analyze the problem further. Using the PBLM, they may also request laboratory tests. The PBLM may also provide answers to queries (patient directed questions or physical examination) that were erroneously overlooked in the actual patient encounter. During the tutorial meeting, the emphasis is on collaboration and self-directed learning; the students explore the case for data, propose and argue hypotheses, and exchange knowledge. A

student, appointed as "scribe", is tasked with recording the deliberations of the group. The information gathered is categorized as follows: Data—information discovered about the patient, Ideas—hypotheses proposed about the nature of the clinical problem, Learning Issues—identified knowledge deficiencies within the group with relation to the clinical case, and Actions—proposals for further evaluation of patient or managing the patient's condition. The work of the coach is to guide and evaluate this exploration process. Following this episode of self-directed learning, the students are allowed to proceed with individual study to rectify identified individual and group knowledge deficiencies.

Utilizing various resources such as libraries and human expert sources, the students complete their individual study. The group then reconvenes for a continued examination of the problem, applying their newly acquired knowledge to the process. Again, the collaborative process follows the practice of the earlier tutorial session—the continued progress of the group is recorded by the scribe, with the coach guiding and evaluating the process. This two step phase of collaborative exploration and independent study is repeated until every member of the group is satisfied that the problem has been sufficiently explored.

Once the group has successfully explored the problem, they next proceed to examine the case in context of other cases they have seen. This is called the abstraction phase. The idea is to force the students to articulate the knowledge acquired, to make generalizations between cases where possible, to identify connections between lessons learned across cases, and to identify similarities and differences among cases.

Finally in the reflection phase, the group does a self critique of the clinical reasoning process they followed in the case, thus accomplishing an "abstracted replay" (Collins, Brown, & Newman, 1989). The abstraction and reflection stages are intended to make the student aware of the whole problem exploration approach and to identify areas for future improvement.

The Problem-Based Learning Module (PBLM)

The PBLM is a text-based simulation of the patient encounter and laboratory tests. It provides responses to questions that a physician might direct to a patient, observations that a physician may make during a physical examination of the patient, and results of laboratory tests that a physician might request. A PBLM contains a database of responses to all possible queries (questions, physical examinations, laboratory tests) that a physician might make of a particular patient. The PBLM thus provides a complete simulation of a patient encounter as well as pertinent laboratory test results. All data items in the PBLM are indexed in an external reference (i.e., the "PBLM User's Guide"). The PBLM was designed to avoid cueing the student as to the appropriate questions to ask.

The Traditional PBL classroom

In the traditional PBL meeting, two students are appointed to serve the role of "scribe" and a "narrator". As described above, the scribe records the groups deliberations on the board. In the process of exploring the case, student queries may require reference to the PBLM. The job of the narrator is to read data items from the PBLM to the group. The job of the coach is to guide the exploration process and ensure that haphazard guessing and arbitrary reference to the PBLM does not take place.

At this time, it is important to note the information exchange and presentation that occurs in a PBL classroom. Students take notes of the team's progress as recorded on the board as well as their own private notes for subsequent use. Following an episode of individual study, students exchange new information individually discovered. Typically information is disseminated in the form of photocopies and resource (e.g., texts, journals) references.

Information presentation takes various forms. The patient itself may be human or simulated by the PBLM. Most information presented by the PBLM is textual, but may include pictorial and graphic information, and laboratory type media such as X-rays, tissue samples, etc. To enable laboratory type presentations, the PBL classroom may include light boxes for X-ray examination, and microscopes for the examination of tissue slides.

The Collaborative Learning Laboratory

The Collaborative Learning Laboratory (CLL) (Koschmann, et al, in press) is an experimental platform for research into electronically-supported collaborative instruction. The Laboratory is intended to augment collaborative learning practices, through technological support using various hardware and software tools. The CLL achieves this by providing hypertext/hypermedia (Conklin, 1987) facilities, groupware (Stefik & Brown, 1989) and database facilities, LAN technologies, and Internet links. In this section we focus on a CLL learning laboratory configuration tuned to augment PBL.

The CLL is comprised of a set of Macintosh workstations linked by a LAN. A router provides Internet access for all computers in the LAN. A video circuit links each computer's monitor output into a selector switching device connected to an overhead public display projector. Other sources of composite video output (e.g., video disc, remote video cameras, video

conferencing equipment) can also be patched into the switch box. This allows the output of any computer screen or other video source to be projected onto the overhead public display.

Three elements of the CLL play a crucial role in the augmentation of the PBL classroom and require lengthier discussion. They are: e-talk—an electronically supported conversation (ESC) facility (Koschmann, 1993), the Teaching Case Library; and the Clinical-Encounter Simulation Stack—a hypermedia database substitute for the PBLM.

E-Talk The Electronic Collaboration Support Element

E-talk (Koschmann, 1993) was developed as an experimental platform for investigating the affordances of electronically-supported conversation (ESC) in classroom instruction. Conceptually, e-talk is similar to the talk utility in UNIX; it provides added functionality including the provision for remote conferencing. It provides users with the ability to carry out typed conversations over a computer network in real-time. Text typed on one workstation is instantly displayed on the other participants' screens. Typically each user has two windows: a window in which to type messages (termed a dispatch window) and a window in which received messages are displayed (termed a listener window).

E-talk allows dispatches to be sent to multiple recipients. Thus a conversation can include more than two people. Further, a user can be involved in multiple independent conversations, as though they had an array of phones over which to converse. Each dispatch window is linked to a specific listener or set of listener windows. Both listener and dispatch windows offer simple word-processing functionality. Text typed into a dispatch window is transmitted to designated recipients through a dispatch command. Messages received by a Listener window are appended to the bottom of the current text in the window, providing a reviewable and editable transcript of the conversation. Every message includes a time-stamp and address (user defined name) of the dispatch window in which it originated.

Unlike the UNIX talk utility, e-talk opens listener windows and dispatch windows independently of each other. Whenever a listener window is opened, it is recorded in a central registry using a unique user defined name. When a dispatch window is opened the user is prompted to select a listener (or listeners) from a menu of known listener windows. The user can have several dispatch channels open simultaneously by opening multiple dispatch windows each addressing different sets of recipients—each channel representing a separate private conversation/conference. Similarly, the user can open multiple listener windows, each receiving dispatches from different users. Note that since a listener window is addressable by more than one user, it allows a many-to-one functionality. Finally, a dispatch windows can be defined to be "broadcast" windows—permitting them to broadcast to all known listener windows (except those explicitly prohibiting reception of broadcast-type messages).

Using the functionality provided, various participation configurations are possible. Users can participate in multiple independent conversations/conferences. Users can participate exclusively as listeners, exclusively as speakers, or as both speakers and listeners in a particular conversation.

The Teaching Case Library

The Teaching Case Library (TCL) is a repository of case data drawn from actual clinical cases. For each clinical case (patient encounter) the data includes responses to all possible interview queries, physical examination probes, and laboratory tests. The database is maintained as an integrated relational database of all prepared clinical teaching cases. Using relational database techniques, a single clinical case (PBLM) can be extracted into a separate independent database. This facility allows individual clinical cases to be extracted and incorporated into a variety of presentation formats, including the conventional PBLM textual format or into computer-based, hypermedia formats.

The Clinical-Encounter Simulation Stack

The Clinical-Encounter Simulation Stack (CESS) is a *HyperCard*-based, multimedia database providing the same functionality as the PBLM. CESSs can be generated automatically using data extracted from the TCL.

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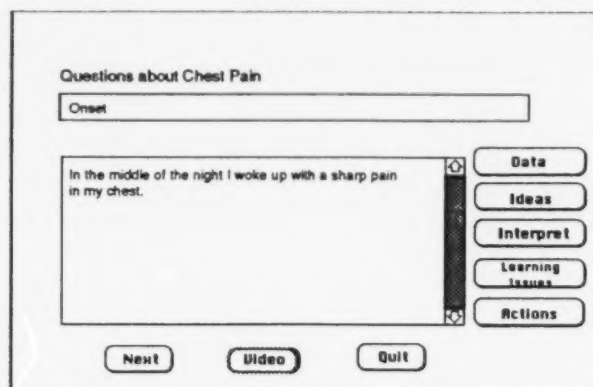


Figure 2. Shows an example of a user screen from the CESS

The user identifies the type of query to be made: Interview, Examination or Laboratory Test. The user then types in query or request for information. CESS responses may be in text or other media. For example, laboratory data such as an X-ray copy may be displayed using a computer bit map, video (VCR) or an actual X-ray photograph; a patient's heart beat may be presented audibly. Similarly, a patient's response to an interview question or an exam item may be presented in video form, with particular queries indexed directly to relevant segments of video. Thus a data record may be a segment of text, a segment of video, an audio segment, a computer graphic, a video frame, or an X-ray photograph. The multimedia environment offers multiple options for presenting case-related data. Special media and computer-interfaceable devices are used to present audio and video data. Appropriate device commands and medium indices are incorporated into the Teaching Case Library (and the extracted CESS).

The CLL Augmented PBL Classroom

We now look at how the PBL classroom works with the facilities afforded by CLL. The CLL and its associated software is designed to allow PBL participants (both students and faculty) great flexibility in adapting its resources to meet the needs of the group. Great care was taken to ensure that the introduced technologies do not interfere with the valued discussions that occur in PBL meetings.

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The Configuration of the Classroom

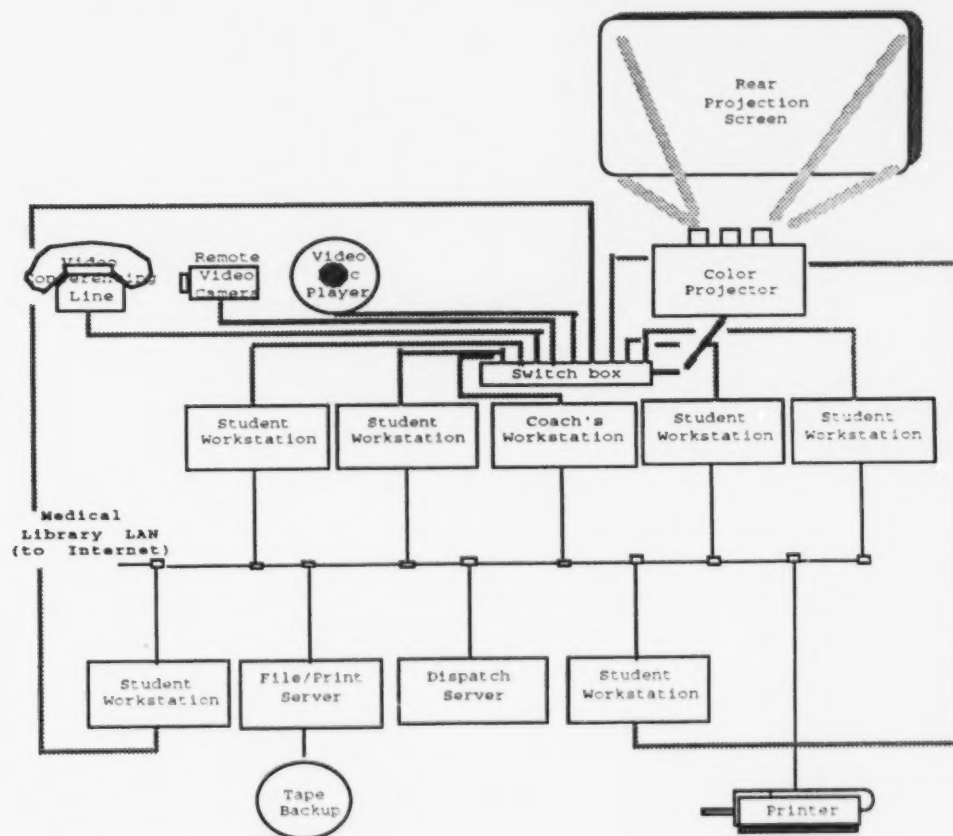


Figure 3.

As shown in Figure 3, every student in the CLL is provided with a workstation running e-talk. Students also run other applications locally (e.g., word processors, graphic software).

E-Talk set-up

The following is a description of an e-talk configuration for the PBL classroom. At the discretion of the coach, other configurations may be implemented. A multiway simplex channel is set up between the scribe and every other member of the team. This allows the scribe to distribute copies of the shared information which he/she maintains. In addition, we have

experimented with a multiway full duplex channel between the coach and every student. This allows the coach to conduct private conversations with students in an otherwise open forum. Members of the team are also allowed to implement their own private channels, allowing other private conferencing and conversations to occur.

The Narrator

In the PBL classroom, the narrator is responsible for referencing the PBLM and narrating the information found to the team. In the CLL, the CESS is currently loaded into the narrator's workstation. The narrator's workstation is also wired to control other media devices, such as video and audio devices. Responses from the CESS are then displayed at the narrator's monitor and from there projected to the public screen.

The Scribe

In order to maintain the team's shared information the scribe is provided with software that allows him to open a four-paned editable window on the workstation. The four panes are independently scrollable and are used to maintain the four categories of shared information: Data, Ideas, Learning Issues and Actions. The scribe's computer desktop, like that of the narrator's, can be projected on the public screen. The information compiled by the scribe is maintained as a reviewable record of the team's deliberations.

A PBL Tutorial Session

The PBL session proceeds in the fashion outlined in Section 2 with minor modifications. The scribe maintains the team's shared information on what is conceptually an electronic blackboard. The PBLM is available as a computer-controlled, hypermedia database. Information can be exchanged electronically using e-talk. While the process of examining the clinical case remains as outlined in Section 2, it is necessary to examine the innovations allowed by the introduction of technology.

Information Collection and Distribution

Students use text and graphic editors on their workstations to make private notes. Since most information is maintained electronically, the dissemination of information is facilitated using e-talk. Further, if members are required to post their contributions to the team's shared information window (currently maintained by scribe), they will be forced to better articulate their ideas (Koschmann, et al., in press). During individual study, information gathered electronically from sources such as scanners, on-line medical library facilities, and E-mail, can be easily presented and disseminated to the rest of the group using e-talk.

The ability to access geographically-remote information can also be carried out in the classroom. Since e-talk allows channels to be set up across the Internet, it is possible to set up an electronic conference with remote consultants. Besides conferencing, remote databases and libraries can be accessed directly from the classroom. The team can compose and send E-mail (presumably to query remote experts) as well as receive E-mail replies during tutorial sessions.

An important aspect of information handling in the CLL is that a permanent and editable copy of all information can be easily maintained. In contrast with the traditional use of blackboards and notebooks, this ability to maintain a retrievable record of the group's deliberations constitutes an important feature of working in the CLL.

Private Channels in an Open Forum

The ability to establish person-to-person e-talk channels allows participants to carry on private conferences in an otherwise open forum, a feature we have termed "a private channel in a public forum" (Koschmann, et al., in press). For example, the coach can make use of this facility to poll each student independently. This forces members to contribute opinions and reduces domination of the process by only some members. This facility also allows the coach to evaluate individual students.

Archiving

The electronic information support by CLL allows students to archive every clinical case they encounter. This archive not only includes the case data but the entire analysis process followed by the team as recorded by the shared information resource maintained by the scribe, the students' private notes, and other information collected during the PBL process for the case. This archive can be subsequently indexed at the students' discretion, and used in the Analysis phase of PBL for other cases.

Building PBLMs and the Teaching Case Library

Creating a PBLM is a non-trivial task involving gathering all pertinent information regarding the case (interviews, examinations, tests etc.). This information must then be carefully examined, partitioned and indexed to provide a database that can be queried productively during case analysis. Designers need to ensure that only relevant information is revealed in

response to a query; also responses should not provide cues to students as to follow-up queries. There is a need to ensure that responses are entered for all possible questions. With the traditional text-based module using question categories to index into the module, there is a necessity to elaborate on responses to questions so as to limit the need for follow-up questions and ultimately on the size of the module.

The use of an a computer database (TCL) has all the advantages of electronic text handling. Using keyword identification techniques reduces the cueing problem of traditional modules. Employing a relational computer database reduces the problem of including individual responses to every question; since the module (CESS) used for a particular case is dynamically generated from the TCL. The integrated database allows common information to be shared across cases, and building a new module is facilitated by information already present in the library.

Updating the Teaching Case Library

The traditional method implements a PBLM as a text book. Non-trivial update of such a module invites all the problems of updating any paper-based text resource. Relational databases on the other hand are easily updated to correct errors or include supplemental information.

Discussion

We are currently in the process of evaluating the CLL and its effects on process in the PBL meeting. The introduction of technologies such as those described in this paper may effect these meetings in subtle and, as yet, not well understood ways. Furthermore, the effects are not stable in that as the participants become more accustomed to introduced technologies, they may come to use them in new ways, including some which may not have been anticipated by the developers.

Therefore, to help us understand what these innovations mean to the PBL participants, we are undertaking a number of observational studies of PBL meetings—both augmented and unaugmented by technology. In an earlier paper (Koschmann, et al., in press), we attempted to articulate what constituted exemplary performance in a PBL meeting. This we presented in the form of six principles. Using ethnographic methods, we are now investigating to what degree these principles are honored in practice. Through this approach we hope to eventually answer the central question which is: how is the character of a PBL meeting changed when conducted in the CLL?

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